

**PHYTOTOXICOLOGY ASSESSMENT
SURVEY INVESTIGATIONS ON
CORNWALL ISLAND IN ONTARIO
IN THE VICINITY OF THE
REYNOLDS METAL COMPANY (RMC)
MASSENA, NEW YORK
1989 & 1991**

MARCH 1993

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Ontario

**Ministry of
Environment
and Energy**

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Report prepared by:

Phytotoxicology Section
Air Resources Branch
Ontario Ministry of the Environment
ARB-014-92-Phyto

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- 1989 AND 1991**

EXECUTIVE SUMMARY

A Federal-Provincial study with participation by several government agencies, including the Phytotoxicology Section, Ontario Ministry of the Environment, has been ongoing for several years on the Cornwall Island Indian Reservation (Mohawks of Awkwesasne). Phytotoxicology investigations, involving vegetation sampling and injury observations, to assess the impact of airborne fluoride emissions from the Reynolds Metals Company (RMC), Massena, New York, on vegetation on Cornwall Island, have been conducted during the growing season annually since 1969, except in 1988 and 1990. The 1988 survey was discontinued because of budget constraints. There was no survey in 1990 because of internal unrest on the reserve. This report presents the results of the most recent investigations on Cornwall Island during 1989 and 1991.

In both years, the highest degree of foliar contamination and most severe vegetation injury was observed in the vicinity of the S shore bridge area, as in previous years.

In 1989, fluoride levels in maple foliage and forage decreased slightly from 1987 levels and were amongst the lowest to be detected since the survey began. In contrast, fluoride levels in Manitoba maple foliage in the S shore bridge area in 1991 were markedly higher than 1989 and 1987 levels. Fluoride levels in forage also were increased in the survey area in 1991.

The Upper Limit of Normal (ULN) rural guideline for fluoride in tree foliage (15 ppm) was exceeded at several sites in both years. Fluoride levels in maple foliage in the S shore bridge area in 1989 (140 ppm) and 1991 (375 ppm) were several times higher than the ULN. The ULN for forage (12 ppm) was consistently exceeded at the S shore bridge site in both years, as well as at the N. Point site in 1991.

Foliar inspections in 1989 and 1991 revealed no major change in the degree and extent of injury from the previous year.

The increase in fluoride levels in vegetation in 1991 corresponded with an increase in ambient fluoride levels in the S shore bridge area. Weather conditions were also a contributor to the increase in vegetation fluoride levels on Cornwall Island in 1991.

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- 1989 & 1991**

I. INTRODUCTION

A Federal-Provincial study with participation by Environment Canada, Agriculture Canada, National Health and Welfare, Indian and Northern Affairs and the Ontario Ministry of the Environment (MOE) was established on Cornwall Island in Ontario in 1975. Prior to this, the Phytotoxicology Section had been conducting annual vegetation assessment programs and responding to complaints concerning the adverse effects of airborne fluoride emissions on vegetation and cattle since 1969. The source of the fluoride emissions was identified as the Reynolds Metals Co. (RMC) , located in Massena, New York. The study was broadened in 1975 in view of the transboundary nature of the emissions and their impact on the Awkwesasne Mohawk Indian Reserve on Cornwall Island.

Vegetation assessment surveys have been conducted by the MOE Phytotoxicology Section during the growing season without interruption since 1969, with 1988 and 1990 being the only exceptions. The 1988 survey was discontinued in June because of budget constraints. There was no Phytotoxicology survey in 1991 because of internal unrest on the Awkwesasne Reserve.

The results for all earlier year's vegetation assessment programs through to June 1988 have been previously reported. This report presents the results of the most recent investigations in 1989 and 1991 on Cornwall Island.

II. VEGETATION ASSESSMENT PROGRAM - 1989 AND 1991

A. OBJECTIVE

The primary objective of the 1989 and 1991 Phytotoxicology programs was to determine the degree and extent of fluoride contamination and injury to vegetation on Cornwall Island and to compare the findings with previous years' results.

B. SAMPLES COLLECTED FOR CHEMICAL ANALYSIS

Maple Foliage & Forage Sampling in 1989

In mid-August, Manitoba maple foliage was collected from exposed middle branches at the ten sites (1, 2, 3, 6, 7, 8, 9, 20, 21, 33) that were regularly sampled in previous years on Cornwall Island (Figure 1). In addition, foliage was sampled from an exposed red maple tree in each of the S shore area woodlots (W and E of bridge) and on the N. Point property in June, July and August. These red maples were also sampled in previous years.

In addition, the eight established forage sites on Cornwall Island were sampled monthly from May to October, as has been the case since 1978 (see Figure 2). Prior to 1978, forage sampling was performed only in June, July and August.

Maple Foliage & Forage Sampling in 1991

In 1991, the sampling of the ten Manitoba maple sites in mid-August was repeated, as was sampling of the three red maple sites in June and August.

Sampling at the eight forage sites was reduced from six (May to October) to three (June to August) monthly collections, as in earlier years (1969 to 1977).

C. SAMPLES COLLECTED FOR HISTOLOGICAL EXAMINATION

In both 1989 and 1991, vegetation with "fluoride-like" injury symptoms were collected for histological examination. These foliar samples were placed in preserving fluid in glass jars until examined in the Phytotoxicology histology laboratory.

D. SAMPLE SUBMISSION FOR CHEMICAL ANALYSIS

The tree foliage and forage samples collected for chemical analysis in 1989 and 1991 were returned to the Phytotoxicology processing laboratory. All samples were processed as "unwashed" samples, with the exception of the August 1989 Manitoba maple foliage samples. These were processed both unwashed and washed. All samples were oven-dried, ground and stored in glass jars. They were then submitted to the MOE Laboratory Services Branch for fluoride analysis. The August Manitoba maple samples in both years were also analyzed for aluminum and sodium, as were the red maple samples in 1991 (June & August). The foliage from Manitoba Site 1 in August 1991 was also analyzed for numerous other elements (see Table 7).

E. VEGETATION INJURY ASSESSMENT PROGRAM - 1989 & 1991

As in previous years, vegetation (cherry, maple, sumach, pine, wild and cultivated grape,

gladiolus, vegetable crops etc.) on Cornwall Island was inspected for foliar fluoride injury to the NE of RMC, as well as at other locations from June through August in 1989 and 1991. Pine needle inspections were continued through to mid-September.

III. RESULTS OF THE VEGETATION ASSESSMENT PROGRAM IN 1989

A. Analytical Results for Maple Foliage and Comparison to MOE Upper Limit of Normal Guidelines

Fluoride Results

In 1989, the highest fluoride concentrations in Manitoba maple foliage in August were detected at Site 1 (140 ug/g) in the S shore bridge area of Cornwall Island. At the remainder of the sites, the concentrations ranged from 8 to 76 ug/g. Foliar concentrations of fluoride decreased with increasing distance from this area and from RMC (Table 1).

The highest fluoride levels in red maple foliage were also found in the same general area (E-of-bridge woodlot site). Red maple had higher fluoride concentrations in July or August than in June at all sites. The June and August results are shown in Table 5. The July results were: W-of-bridge woodlot - 46 ug/g; E-of-bridge woodlot - 55 ug/g; N. Point site - 54 ug/g.

In Manitoba maple foliage, fluoride concentrations in August 1989 were slightly reduced overall compared to 1987, being amongst the lowest detected (Table 1). The June and August fluoride levels in red maple foliage also were reduced from 1987, particularly at the E-of-bridge site and on the N. Point property (Table 5)

The average contribution of particulate surface contamination to the total fluoride level at most Manitoba maple sites in August also was reduced in 1989 in comparison with earlier years. The particulate removal values found in the survey area in 1989 were amongst the lowest detected (Table 2).

In 1989, the concentration of fluoride at five of the ten Manitoba maple sites in August exceeded the Phytotoxicology Section Upper Limit of Normal (ULN) rural guideline of 15 ug/g in unwashed foliage. This was a reduction, compared to nine sites in 1987, ten sites in 1986 and nine sites in 1985. The three red maple sites also exceeded the 15 ug/g ULN each month (June to August), with exception of the woodlot site W of the bridge in June.

Aluminum and Sodium Results

The highest aluminum and sodium levels in August also were detected at Manitoba maple Site 1 (Al 91 ug/g; Na 275 ug/g), as in most other years (Table 3 & 4). As with fluoride,

foliar aluminum concentrations overall in 1989 (August) were reduced from 1987 levels and were among the lowest detected. In contrast, sodium levels overall were increased in 1989 from 1987 and 1986 levels, particularly at Sites 1 and 21, which were closest to RMC. However, sodium levels in 1989 (August) were generally not as elevated as earlier survey (1982-1985) results.

The Phytotoxicology Section rural ULN guideline for aluminum (500 ug/g) was not exceeded in 1989, or in any other survey year shown in Table 3. In contrast, the 50 ug/g rural ULN for sodium was exceeded at eight Manitoba maple sites in August 1989, compared to eight sites in 1987, seven sites in 1986 and eight sites in 1985.

B. Fluoride Results for Forage and Comparison to MOE ULN and Forage Criteria

As in earlier years, the highest fluoride levels in forage from May to October were detected at the S shore bridge site, which was closest to the NE of RMC (see Figure 2). At this site, fluoride concentrations in 1989 ranged from 11 to 48 ug/g over the six-month collection period. The monthly data displayed a decreasing pattern with increasing distance from this area (Table 8). The historical summaries of the seasonal site means for May to October (Table 9) and for June to August (Table 10) revealed a slight decrease in fluoride levels at most forage sites in 1989 compared to 1987. Fluoride levels in forage on Cornwall Island in 1989 were among the lowest since the survey began: only 1986 had a lower overall seasonal mean concentration.

The Phytotoxicology Section Upper Limit of Normal (ULN) forage guideline of 12 ug/g fluoride was exceeded at seven of the eight forage sites in July 1989 versus 1 to 3 sites in other months (Table 8). Although the Bridge site consistently exceeded the ULN, none of the sites exceeded the one (80 ug/g), two (60 ug/g) or six (35 ug/g) consecutive month MOE forage criteria (based on health of grazing animals). The MOE forage criteria was exceeded once in 1987 compared to no exceedances in 1986 and a single exceedance in 1985. A higher number of exceedances was recorded in 1984 (11), 1983 (4) and 1982 (3). Over the years, exceedances of the MOE forage criteria have been primarily confined to the Bridge site in the S shore bridge area.

C. Results of Visual Injury Assessment

As in previous years, the most severe fluoride-type foliar injury generally was observed in the S shore bridge area to the immediate NE of RMC. The results of the foliar inspections in 1989 are discussed below. The August injury ratings are compared to the 1987 results, since the 1988 survey was discontinued in June.

Cherry and Plum trees - Inspections from June to August revealed fluoride-type necrosis on a black cherry tree and pin cherry in the S shore area (W of bridge), and on the two black cherry trees on the slightly more remote A. Boots property. Foliar injury on the pin cherry was rated as trace (>0-1%) to light (2-10%), but was closer to trace overall. On

the black cherry trees, a few leaves had moderate (11-35%) to severe (>35%) injury, but the overall injury at both locations was closer to light (2-10%). Histological analysis confirmed that the leaf samples collected from both areas in August had typical fluoride induced injury. However, the observations did not implicate fluoride as the cause of all of the injury on these trees. Other cherry trees (choke, pin) in these areas had missing tissue (a feature associated with advanced fluoride-induced injury) on tips/margins of some leaves, but fluoride-type necrosis was not observed.

The plum trees examined in the vicinity of the S shore bridge area also exhibited leaves with absent tissue, but no fluoride-type necrosis. Plum foliage on the Elijah Benedict property (center of Island) had trace (>0-1%) to light (2-10%) foliar injury (reddish-brown marginal necrosis) in July. However, by August, the necrosis had abscised and the trees appeared green. Because RMC was 4 km distant, the fluoride level of the maple foliage collected on this property in August was low (15 ug/g), and the necrosis was not observed on plum trees (plum plot, A. Boots, L. Point, Earny Benedict - see Figure 1) closer to RMC, it is questionable that fluoride was involved. Injury to cherry and plum trees in the S shore bridge area was less severe in 1989 compared to 1987.

Wild and Cultivated Grape - Some wild grape at observation sites close to the river (E and W of bridge) had moderate (11-35%) or severe (>35%) injury on a few leaves, but these sites had closer to light (2-10%) injury overall. Injury to other affected grape sites in the S shore-bridge area was trace (>0-1%) or trace-to-light overall. In August, trace or very light injury (primarily tip necrosis) was observed at most wild grape sites through to the remote east end of the Island. However, as fluoride levels at the remote maple sites (Site 6, 7, 8, 9, 20) were low (15 ug/g or lower) in August, injury at these sites was not suspected to be due to fluoride. Insects were more likely responsible for the injury. Injury to wild grape in the S shore bridge area in August was similar to 1987.

Cultivated grape was inspected on the A.Boots property (S shore bridge area) in July and August, and on the Earny Benedict and A. Lazore properties (more remote NE of RMC) in August (see Figure 1). In July and August, some mature leaves in the Boots garden had trace (>0-1%) to very light (2-10%) necrosis (tip injury mainly), but only trace injury overall. No injury was observed on the Benedict property and only a few grape leaves had injury (tipping) on the remote A. Lazore property (S end of island). The injury on the Lazore property was not suspected to be related to RMC, as the maple foliage on this property in August had a normal fluoride level (13 ug/g). Injury to cultivated grape on the Boots property was similar to 1987.

Maple trees - From June to August, a few Manitoba maple trees in the general vicinity of the S shore-bridge area had a few leaves with fluoride-type injury (orange-tan necrosis in sinus areas), with the injury being trace (>0-1) overall. However, histological analysis of the injured leaves from an affected young Manitoba maple beside the river (E of bridge) did not implicate fluoride as the causal agent. By August, Manitoba maples throughout the survey area exhibited several leaves with orange/reddish brown tip

necrosis, including remote collection Sites 7, 9 and 20, where fluoride levels were low (15 ug/g or lower). Therefore, Manitoba maple was not considered to be a reliable fluoride indicator in 1989.

In June, red maples in the S shore woodlots (E and W of bridge) had foliar injury typical of Late Spring Leaf Scorch (LSLS). In August, these trees had reddish-brown necrosis at the tip and/or margins of some leaves, with the injury severity at both sites being trace (>0-1%) overall. This injury was not observed on the red maple on the N. Point property in August. As both woodlot maples (E and W of bridge) in August had a fluoride level (48 & 64 ug/g) similar to the non-injured foliage (44 ug/g) collected from the slightly more remote N. Point property, it is questionable that the injury in the S shore woodlots in August was related to fluoride. However, the histological results (Table 12) suggested that fluoride may have contributed to some of the injury. Regardless, the foliar injury to these trees was very light overall in August, and was less severe in 1989 than 1987.

Serviceberry and Trembling Aspen - The small serviceberry tree beside the river (W of bridge) had fluoride-type reddish-brown necrosis from June to August. Most leaves had tip injury in June and July, but by August most of the necrosis had abscised and only some leaves exhibited fluoride-type necrosis. The injury to this tree each month was trace (>0-1%) to very light (2-10%) overall. A few young trembling aspen trees in the S shore area (W of bridge) also had some leaves with blackish tip necrosis of trace severity. By August, the injury had abscised from most leaves. Both species had less injury in 1989 than 1987.

Staghorn Sumach - As in previous years, unusual injury (tip/marginal/interveinal brown or blackish necrosis) was observed mainly on mature sumachs in the S shore bridge area. At most sites, only some mature leaves were injured, with younger leaves being unaffected. At the most severe site (river area E of bridge), both mature and young sumachs had injury on both mature and younger foliage, with the injury severity being light (2-10%) to moderate (11-35%) overall in August. Other sumachs in the S shore bridge area in August had trace (>0-1%) to light injury overall. As in previous years, injury was not observed at remote sumach sites, an indication that RMC emissions were involved. Sumachs in the S shore bridge area were not as severely injured in 1989 as 1987.

Pine Needle Assessment - As in previous years (1984-1987), the inspection of current year pine needles through September revealed fluoride-type injury on a few red pines on the N. Point property. The overall injury to the trees was trace (>0-1%) and the histology results implicated fluoride as the cause. The injury severity was similar to 1987.

Gladiolus and Garden Crops - In the vicinity of the S shore bridge area, gladiolus was observed only on the E. Francis (across the road from L. Point) and N. Point properties (see Figure 1). By August, the gladiolus on both properties had fluoride-type tip and/or marginal reddish necrosis extending down one or both margins of several leaves. In

August, the white-flowered gladiolus on the Francis property had light (2-10%) to moderate (11-35%) injury overall, while gladiolus on the N. Point property had trace (>0-1%) injury overall. The gladiolus on the N. Point property exhibited less injury in 1989 than in 1987.

Island garden crops also were inspected in July and August, but no injury that could be attributed to fluoride emissions was observed.

D. Histology Analysis Results

In 1989, foliar examination in the Phytotoxicology histology laboratory confirmed fluoride as the causal agent inducing injury on black cherry foliage (S shore area, A. Boots property), red maple foliage (E-of-bridge woodlot), and on red pine needles (N. Point). The specific observations have been noted above in discussions of individual species injuries.

IV. RESULTS OF VEGETATION ASSESSMENT PROGRAM IN 1991

A. Analytical Results for Maple Foliage and Comparison to MOE ULNs

Fluoride

As in previous years, Manitoba maple at Site 1 (S shore bridge area) had the highest fluoride levels in August 1991, with levels at more remote sites being sharply lower (Table 1). The level of 375 ug/g at Site 1 was more than double the 1989 (140 ug/g) and 1987 (149 ug/g) concentrations, but was similar to those that were found from 1982 to 1985 (293-389 ug/g). Fluoride levels at a few other sites close to RMC were marginally increased compared to 1989 and 1987.

In red maple foliage, the highest fluoride levels were detected at the E-of-bridge woodlot site (just E of Manitoba Site 1), where the fluoride level in August (195 ug/g) was slightly higher than in June (160 ug/g). The woodlot site W of the bridge, and the slightly more remote N. Point site, had lower levels in August than in June. In June, fluoride levels at all sites were higher than for other June surveys conducted from 1984 to 1989. The August level at the E-of-bridge site (195 ug/g) also was higher than in previous surveys (1984-1989) except 1984 (278 ug/g) (Table 5).

Six of the ten Manitoba maple sites in August 1991 exceeded the Phytotoxicology rural ULN (15 ug/g) compared to five sites in 1989, nine sites in 1987 and ten sites in 1986. The three red maple sites in June and August also had a fluoride level greater than the ULN.

Aluminum, Sodium and Other Elements

In August 1991, the highest concentrations of aluminum (390 ug/g) and sodium (325 ug/g) were detected in Manitoba maple foliage at Site 1, with concentrations decreasing with increasing distance from this area and RMC. In red maple, the highest concentrations were detected in June at the E-of-bridge (Al 265 ug/g) and N. Point (Na 140 ug/g) sites. Concentrations of both elements in red maple were generally lower in August, with the exception of the marginally higher aluminum level at the W-of-bridge site.

In 1991, none of the Manitoba or red maple sites exceeded the 500 ug/g rural ULN for aluminum. The rural sodium ULN (50 ug/g) was exceeded in Manitoba maple at eight of ten sites in August. In red maple, the sodium ULN was exceeded at the E-of-bridge site in both June (131 ug/g) and August (57 ug/g) and at the N. Point site (140 ug/g) in June. The highest foliar concentration of sodium (325 ug/g - Site 1) was 6.5 times higher than the rural ULN. At Manitoba maple Site 1, where concentrations of fluoride, aluminum and sodium were elevated in August, foliar concentrations of other elements (see Table 7), though generally higher than at remote Site 7, did not exceed the ULN guidelines.

In Manitoba maple foliage (August 1991), concentrations of aluminum at most sites were increased from 1986-1989 levels, with the level at Site 1 (390 ug/g) being the highest detected since 1982. The sodium concentration at Site 1 (325 ug/g) in 1991 was marginally higher than 1989 (275 ug/g) and markedly higher than 1987 (105 ug/g), but was lower than previous results (1982-1985).

B. Fluoride Results for Forage and Comparison to MOE ULN and Forage Criteria

As in earlier years, the highest monthly fluoride levels in unwashed forage in 1991 were detected at the Bridge site in the S shore area. As with maple foliage, fluoride levels in forage decreased with increasing distance from RMC (Table 8).

In 1991, forage sampling was conducted only in June, July and August and the corresponding monthly fluoride results and seasonal three-month means are shown respectively in Tables 8 and 10. Table 10 shows that fluoride levels increased marginally at most forage sites in 1991 compared to 1985 to 1989. However, as shown in Table 10, the 1991 means were not as high as some previous survey results (1977-1978, 1981, 1984).

The 12 ug/g ULN guideline was exceeded each month at the Bridge site and at N. Point and on one or two occasions at the P. Hopps, Dump and E. Benedict forage sites (Table 8). The MOE single (80 ug/g) and two month (60 ug/g) criteria was not exceeded, but the two month (June-July) mean for the Bridge site (worst contaminated) was equal to the two month criterion (60 ug/g). The 1991 site means are not directly comparable to the six-month criterion (35 ug/g), because there were only three monthly collections in 1991.

C. Results of Visual Injury Assessment Program

Inspections of vegetation on Cornwall Island during 1991, as in previous years, revealed the most severe fluoride-type foliar injury in the S shore bridge area to the immediate NE of RMC. The severity of injury that was observed from June to August in the S-shore bridge area and on neighbouring residential properties (L. Point, N. Point, A. Boots) is shown in Table 11 and discussed below.

Cherry and Plum Trees - The most severe fluoride-type injury on black cherry foliage in 1991, as in previous years, was observed on the young tree by the river (W of bridge). From June to August, this tree exhibited several leaves with trace (>0-1%) to moderate (11-35%) injury, but injury to the tree overall was only light (2-10%). However, the histology results indicated that not all of the observed injury in August was attributable to fluoride. A black cherry at the S periphery of the woodlot E of the bridge had trace to light injury in June. Other cherry trees (choke and pin) that were inspected had only missing tissue at tips and/or margins of some leaves. The black cherry trees on the A. Boots property had been cut down.

Plum trees in the S shore area (plum plot) had traces of fluoride-type necrosis and/or missing tissue on some leaves. The plum trees that were inspected in July on the slightly more remote L. Point property had trace (>0-1%) to light (2-10%) injury. The most pronounced fluoride-type injury on plum foliage was observed on the more remote Elijah Benedict property (center of Island). However, as these trees had more severe injury (light to moderate) than plum sites closer to RMC, it is questionable that fluoride was the primary cause.

Injury to cherry and plum trees in the vicinity of the S shore bridge area was slightly more extensive in 1991 than 1989.

Maple Trees - The most severe fluoride-type injury on maple foliage in 1991 was observed at Manitoba Site 1 and on the red maple in the neighbouring woodlot E of the bridge. In July and August, Manitoba Site 1 had several injured leaves, with the injury to exposed foliage (light to moderate overall) being more severe than on protected foliage. Foliar injury of light severity (2-10%) overall was observed on the red maple. The injured foliage collected at both sites in August had a significantly elevated fluoride concentration (Manitoba-375 ug/g, red maple-195 ug/g), an indication that RMC emissions had contributed to the injury. By August, the injury on other affected Manitoba and red maple trees in the vicinity of the S shore bridge area was trace overall (Table 11). On Manitoba maples, it is likely that at least some of the injury was associated with boxelder borer infestation, which can mimic fluoride injury. The mature red maple on the L. Point property also was injured. This is not noted in Table 11, as the injury pattern on this tree did not implicate fluoride as the primary causal agent. The inspections in July and August on silver maples on the A. Boots property, and in the vicinity of the N. Point forage site, also did not reveal any obvious fluoride injury.

Injury to Manitoba and red maple foliage in the S shore bridge area (E of bridge) appeared to be slightly more severe in 1991 than in 1989.

Serviceberry and Staghorn Sumach - The affected serviceberry tree (W of bridge) exhibited light (2-10%) to moderate (11-35%) necrosis, as well as cupping, on most leaves in June 1991. By August, much of the injury had abscised, with remaining injury being trace (>0-1%) to light overall. Injury to this tree was more severe in 1991 than in 1989. Sumach foliage on mature thickets close to the river, just E of the bridge, was the most adversely affected. In August, these sumachs exhibited cupped and savoyed (wrinkled) mature leaves with light (2-10%) to severe (>35%) necrosis, but the overall injury was closer to light to moderate (11-35%). Other affected sumachs (E and W of bridge) had trace (>0-1%) to light (2-10%) injury or light injury overall. Inspected sumachs remote from the S shore bridge area did not display the injury, an indication that RMC emissions had contributed to the injury on the southern part of the island. The injury to sumachs in 1991 was not markedly different than 1989.

Wild and Cultivated Grape - Wild grape plants in the S shore area had trace (>0-1%) injury or trace to light (2-10%) injury overall in August 1991, with exception of the most adversely-affected site (river area, W of bridge), which had light injury (2-10%) overall. Cultivated grape on the neighbouring A. Boots property had trace injury overall in July and August.

Inspections in August beyond the S shore bridge area revealed trace or trace to light injury (mainly tip necrosis) at most of the more remote grape sites that were inspected through to the area of the A. Lazore property (E end of Island), including cultivated grape foliage (trace) on the Lazore property. As this property was about 7 Km NE of RMC, and as the maple foliage collected from this site in August had a low fluoride content (14 ug/g), natural agent(s) were more likely the cause of the injury in the vicinity of Lazore, rather than RMC emissions. In light of the observations, grape foliage in 1991 was judged to be unreliable in tracing out the extent of fluoride injury beyond the vicinity of the S shore bridge area.

Injury to wild and cultivated grape in the vicinity of the S shore bridge area in 1991 was similar to 1989.

Gladiolus and Garden Crops - Gladiolus plants were observed only on the N. Point property in 1991. In August, fluoride-type injury on these plants was trace (>0-1%) overall, as in 1989.

The Island garden crops inspected in mid-July exhibited no foliar injury that was considered to be unusual or attributable to fluoride.

Pine Needle Assessment - In August 1991, white pines in the S shore woodlots (E and W of bridge), and a young white pine on the Martin property (E of bridge), had reddish

tip necrosis on current year needles. Similar injury was observed on one of the red pines on the slightly more remote N. Point property. However, the pine inspections more remote from RMC (a young white pine had similar injury on remote Lazore property), together with the histology results, did not indicate that fluoride was involved. The injury was possibly due to the dry weather conditions in June and July.

D. Histological Analysis Results

The histological examinations in 1991 revealed no injury typical of fluoride (Table 12).

V. RESULTS OF ENVIRONMENT CANADA AIR MONITORING PROGRAM AND METEOROLOGICAL ASPECTS FOR 1989 and 1991

Environment Canada has been monitoring ambient fluoride on Cornwall island during the growing season at Station D (Martin property) since 1987, and at Station B (Benedict property) since 1976. A wind recorder has been maintained at Station D since 1987.

In the Environment Canada 1991 report (Ref. 2), the air monitoring results for 1991 were compared to 1988 because of lack of confidence in the 1989 and 1990 ambient air and wind data due to missing data. As the 1988 Phytotoxicology survey was incomplete, for the purpose of the following discussion, the ambient air data for 1991 are compared to 1987. The data for 1987, 1989 and 1991 are summarized in Table 13.

In 1991, the highest 24-hour average gaseous and particulate fluoride levels, as in previous years, were detected at Station D in the S shore bridge area to the immediate NE of RMC. At this station in 1991, gaseous fluoride concentrations (24-hour average) from May to October were higher (0.76 ug/m^3), while corresponding particulate levels (0.24 ug/m^3) were lower, compared to 1987 (0.55 and 0.28 ug/m^3 , respectively). At Station B, 24-hour average gaseous (0.21 ug/m^3) and particulate (0.06 ug/m^3) levels were reduced in 1991 compared with 1987 (0.39 and 0.14 ug/m^3 , respectively).

As shown in Table 13, there was also an increase in the percentage of time the Ontario Criteria, Canada Objectives, and New York State Air Quality Standards (overall) were exceeded at Station D in 1991 compared to 1987. In contrast, at Station B (near center of Island), there was a reduction in the number of exceedances of the air quality limits (overall) in 1991 relative to 1987.

Environment Canada found that the prevailing wind directions in 1991 (May to October) were SW (26.0%), W (15.0%) and N (13.0%). In 1987, winds prevailed from the W (20.9%), NW (16.9%) and SW (15.1%). These results indicate that, in 1991, there was a substantive increase in SW winds carrying RMC emissions over the island.

Table 14 shows the percentage of S, SW and W winds that were recorded at the Ontario

Hydro climatic station, Cornwall, for all years (including 1989) that an undisrupted Phytotoxicology survey was conducted, except 1991. Wind data for 1991 was unavailable when this report was written. The percentage of S, SW and W winds in 1989 (57% total) was not markedly different from 1987 (54%).

Within limits, rain can remove fluoride, especially of the particulate type, by its washing action. This action can be reflected in the analytical results wherein years with high rainfall should have lower fluoride concentrations if other factors are held constant. Conversely, dry years should be associated with higher fluoride values. Table 15 summarizes the rainfall data (Ontario Hydro Station, Cornwall) and shows that weather conditions in 1991 were unusually dry in June and July. In 1989, the amount of rain recorded each month (May to August) was either above normal or close to normal, as was also the case in 1987. However, total rainfall in 1989 was greater than in 1987.

The preceding information suggests that an increase in ambient fluoride concentrations on Cornwall Island (Station D), together with dry weather in June and July, likely contributed to the increase in fluoride levels in vegetation in 1991 compared to 1987. The increase in SW winds from 1987 likely contributed to the increased ambient fluoride levels in the S shore bridge area.

VI. SUMMARY OF RMC SURVEY FINDINGS - 1989 AND 1991

A. Main 1989 Findings and Conclusions

1) RMC emissions during 1989 resulted in the highest levels of fluoride, aluminum and sodium in vegetation in the S shore-bridge area. Foliar concentrations decreased with increasing distance from RMC.

2) Fluoride levels in maple foliage (August) and in forage (May-October) were lower in 1989 than in 1987, being amongst the lowest detected since the survey began. Aluminum levels in maple foliage also were decreased in 1989 and were amongst the lowest detected. In contrast, foliar sodium levels in August had generally increased from 1987 levels, but were lower than levels found in previous years (e.g. 1982-1985).

3) The rural ULN for fluoride in tree foliage (15 ug/g) was exceeded at five of the ten regular Manitoba maple sites in August 1989, while the sodium ULN (50 ug/g) was exceeded at eight sites. The ULN for aluminum was not exceeded. The ULN for forage (12 ug/g) was consistently exceeded at the Bridge site, but none of the forage sites exceeded the MOE forage criteria developed to protect livestock health.

4) The most severe fluoride-like injury to vegetation in 1989, as in previous years, was observed in the general vicinity of the S shore bridge area of Cornwall Island. Foliar inspections did not reveal any major change from 1987, with fluoride-like injury to

deciduous vegetation in this area being slightly reduced overall in 1989.

5) On conifers, fluoride-like injury in 1989 was observed only on red pine needles on the N. Point property as in 1987, with the injury severity being similar in both years.

In conclusion, fluoride levels in vegetation on Cornwall Island were slightly reduced in 1989, and were amongst the lowest detected since the survey began. There was also a slight reduction in injury to vegetation compared to 1987. The highest degree of foliar contamination and most severe injury to vegetation, as in previous years, was confined to the island's S shore bridge area, immediately NE of RMC.

B. Main 1991 Findings and Conclusions

1) RMC emissions during 1991, as in 1989, resulted in the highest levels of fluoride, aluminum and sodium in vegetation in the S shore bridge area.

2) Fluoride and aluminum levels in Manitoba maple foliage in the S shore bridge area in August 1991 were markedly higher compared to 1989 and 1987 levels. Sodium levels also had increased markedly compared to 1987, but were only marginally higher than 1989. Fluoride concentrations in forage also were generally higher in 1991 compared to 1989 and 1987.

3) Six of the ten regular Manitoba maple sites in August 1991 exceeded the rural ULN for tree foliage (15 ug/g). This ULN also was exceeded at the three red maple sites in June and August. The ULN for sodium was exceeded at eight Manitoba maple sites and one red maple site in August and at two red maple sites in June. The forage ULN (12 ug/g) was exceeded each month (June to August) at the Bridge site and at N. Point and at a few other sites on one or two occasions. However, there were no exceedances of the MOE single and two month forage criteria.

4) The most severe fluoride-type injury on vegetation in 1991, as in previous years, was observed in the vicinity of the S shore bridge area. Injury in a few cases was slightly more severe in 1991, but, for the most part, was similar to 1989.

5) Ambient fluoride levels and SW winds were increased at Station D in the S shore-bridge area in 1991, based on comparisons to 1987. Weather conditions in 1991 also were unusually dry.

In conclusion, fluoride levels in vegetation had increased in 1991, with the most substantive increase occurring in the S shore bridge area of Cornwall Island. Vegetation injury in this area was slightly more severe in a few cases but, overall, was not markedly different from 1989. As in previous years, the highest degree of foliar contamination and most severe vegetation injury was found in the S shore bridge area. The increase in fluoride levels in vegetation in 1991 corresponded with an increase in ambient fluoride

levels in the S shore bridge area. Weather conditions (e.g. dry weather, SW wind) contributed to the increase in vegetation fluoride levels on Cornwall Island in 1991.

VII. References

1. Phytotoxicology Assessment Survey Investigations on Cornwall Island in Ontario in the Vicinity of the Reynolds Metals Company (RMC), Massena, New York: 1987 and 1988. Ontario Ministry of the Environment
2. Ambient Air Levels of Fluoride at Cornwall Island, Ontario: May to October 1991. Environment Canada

Table 1: Concentrations of Fluoride in Manitoba Maple Follage on Cornwall Island: August 1977 - 1991

Site No.	Kilometers & Direction from RMC	Concentration* In Unwashed Follage												
		1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1989	1991
1	1.5 NE	<u>750</u>	<u>193</u>	<u>197</u>	<u>143</u>	<u>192</u>	<u>380</u>	<u>293</u>	<u>389</u>	<u>337</u>	<u>159</u>	<u>149</u>	<u>140</u>	<u>375</u>
33	1.9 NE	NR	NR	NR	NR	NR	NR	<u>123</u>	<u>117</u>	<u>71</u>	<u>49</u>	<u>48</u>	<u>55</u>	<u>78</u>
3	3.1 NE	<u>217</u>	<u>32</u>	<u>57</u>	<u>60</u>	<u>86</u>	<u>70</u>	<u>97</u>	<u>113</u>	<u>92</u>	<u>48</u>	<u>59</u>	<u>51</u>	<u>41</u>
6	4.1 NE	<u>56</u>	<u>22</u>	<u>32</u>	<u>23</u>	<u>71</u>	<u>28</u>	<u>48</u>	<u>57</u>	<u>48</u>	<u>25</u>	<u>44</u>	15	<u>29</u>
7	6.8 NE	<u>37</u>	<u>23</u>	<u>21</u>	15	<u>64</u>	15	<u>37</u>	<u>39</u>	<u>33</u>	<u>18</u>	<u>24</u>	13	14
21	1.3 NNE	NR	NR	NR	NR	NR	NR	NR	NR	NR	<u>69</u>	<u>74</u>	<u>76</u>	<u>93</u>
2	2.0 NNE	<u>138</u>	<u>17</u>	<u>31</u>	10	<u>50</u>	<u>25</u>	<u>57</u>	<u>63</u>	<u>50</u>	<u>27</u>	<u>48</u>	<u>35</u>	14
8	1.9 N	<u>45</u>	15	<u>21</u>	8	<u>18</u>	12	<u>27</u>	<u>23</u>	<u>32</u>	<u>19</u>	<u>18</u>	10	7
9	2.5 N	14	7	15	5	<u>26</u>	<u>18</u>	<u>19</u>	14	<u>22</u>	<u>17</u>	14	8	9
20	6.1 ENE	NR	6	15	3	<u>29</u>	<u>17</u>	<u>31</u>	<u>41</u>	<u>26</u>	<u>19</u>	<u>22</u>	15	15
Mean Common Sites		180	39	49	33	67	71	76	92	80	42	47	36	63

* ug/g, dry weight, mean of duplicate (1987 to 1991) or triplicate (1977 to 1979; 1983 to 1986) samples. Single samples were collected from 1980 to 1982.

NR - No Results, samples not collected

Note: Data underlined exceed Phytotoxicology Section Upper Limit of Normal rural guideline of 15 ug/g, see appendix.

Analysis by ion selective electrode since 1982. Alkali fusion method was used in previous years

Table 2: Comparison of Particulate Removal Values for the Manitoba Maple Foliage Samples Collected on Cornwall Island in August 1982 through 1991, Based on the Unwashed (NW) and Washed (W) Fluoride Results

Site No.	Approximate Distance (km) & Direction from RMC	Per cent Decrease in F Concentration (Particulate Removal) of Foliage due to Washing ^a						
		1982	1983	1984	1985	1986	1987	1989
1	1.5 NE	53	41	22	32	47	57	25
33	1.9 NE	NR	50	32	17	18	52	13
3	3.1 NE	31	30	6	10	25	51	12
6	4.1 NE	29	48	33	33	0	32	0
7	6.8 NE	0	59	36	18	0	17	0
21	1.3 NNE	NR	NR	NR	NR	19	20	21
2	2.0 NNE	48	79	8	36	26	35	17
8	1.9 N	33	48	22	34	5	17	0
9	2.5 N	17	32	14	27	18	14	0
20	6.1 ENE	29	55	32	31	21	32	20
Mean		40	49	24	32	12	33	11

a Calculated from formula: $\frac{NW - W}{NW} \times 100$

NR - No Results, samples not collected

Table 3: Concentrations of Aluminum In Manitoba Maple Follage on Cornwall Island: August 1982 - 1991									
Site No.	Approximate Distance (km) & Direction from RMC	Concentration* In Unwashed Follage							
		1982	1983	1984	1985	1986	1987	1989	1991
1	1.5 NE	174	181	193	217	127	101	91	390
33	1.9 NE	NR	131	130	62	45	72	70	115
3	3.1 NE	74	99	107	84	47	62	57	66
6	4.1 NE	32	79	69	78	22	67	27	67
7	6.8 NE	70	110	103	137	41	77	35	95
21	1.3 NNE	NR	NR	NR	NR	29	76	45	84
2	2.0 NNE	96	128	83	90	47	185	68	75
8	1.9 N	51	96	57	115	35	67	31	73
9	2.5 N	49	66	26	58	28	58	13	35
20	6.1 ENE	80	110	81	74	27	51	35	73
Mean Common Sites		78	111	94	102	47	84	45	110
* ug/g, dry weight, mean of duplicate (1987 to 1991) or triplicate (1983 to 1986) samples. A single sample per site was collected in 1982 NR - No Results, samples not collected Note: Phytotoxicology Section Upper limit of Normal rural guideline for aluminum is 500 ug/g, see appendix									

Table 4: Concentrations of Sodium in Manitoba Maple Follage on Cornwall Island: August 1982 - 1991

Site No.	Approximate Distance (km) & Direction from RMC	Concentration* In Unwashed Follage							
		1982	1983	1984	1985	1986	1987	1989	1991
1	1.5 NE	<u>520</u>	<u>373</u>	<u>480</u>	<u>420</u>	<u>137</u>	<u>105</u>	<u>275</u>	<u>325</u>
33	1.9 NE	NR	<u>253</u>	<u>287</u>	<u>160</u>	<u>110</u>	<u>81</u>	<u>145</u>	<u>120</u>
3	3.1 NE	<u>245</u>	<u>157</u>	<u>223</u>	<u>143</u>	<u>84</u>	<u>88</u>	<u>100</u>	<u>105</u>
6	4.1 NE	<u>112</u>	<u>107</u>	<u>109</u>	<u>100</u>	<u>65</u>	<u>61</u>	40	<u>65</u>
7	6.8 NE	48	<u>67</u>	<u>95</u>	<u>89</u>	48	36	<u>64</u>	50
21	1.3 NNE	NR	NR	NR	NR	<u>117</u>	<u>99</u>	<u>205</u>	<u>180</u>
2	2.0 NNE	<u>132</u>	<u>70</u>	<u>85</u>	<u>81</u>	<u>69</u>	<u>91</u>	<u>73</u>	<u>59</u>
8	1.9 N	<u>85</u>	<u>77</u>	<u>68</u>	<u>64</u>	39	<u>57</u>	<u>70</u>	<u>66</u>
9	2.5 N	<u>125</u>	43	<u>61</u>	34	35	36	23	36
20	6.1 ENE	<u>53</u>	<u>77</u>	<u>99</u>	<u>105</u>	<u>74</u>	<u>52</u>	<u>58</u>	<u>56</u>
Mean Common Sites		165	136	167	133	73	67	94	98

* ug/g, dry weight, mean of duplicate (1987 to 1991) or triplicate (1983 to 1986) samples and analysis. A single sample per site was collected in 1982
 NR - No Results, samples not collected
 Note: Data underlined exceed Phytotoxicology Section Upper Limit of Normal rural sodium guideline of 50 ug/g, see appendix

Table 5: Concentrations of Fluoride in Red Maple Foliage on Cornwall Island - June and August, 1984 to 1991

Fluoride Concentration* in June							
Location	1984	1985	1986	1987	1988	1989	1991
S Shore Woodlot - W of Bridge - E of Bridge	<u>69</u> <u>130</u>	<u>18</u> <u>104</u>	<u>20</u> <u>29</u>	<u>25</u> <u>107</u>	<u>42</u> <u>77</u>	12 <u>18</u>	<u>87</u> <u>160</u>
More Remote - N. Point	NR	NR	<u>26</u>	<u>55</u>	<u>79</u>	<u>16</u>	<u>87</u>
Fluoride Concentration* in August							
S Shore Woodlot - W of Bridge - E of Bridge	<u>134</u> <u>278</u>	<u>22</u> <u>139</u>	<u>37</u> <u>43</u>	<u>59</u> <u>109</u>	NR NR	<u>48</u> <u>64</u>	<u>34</u> <u>195</u>
More Remote - N. Point	<u>172</u>	<u>88</u>	<u>42</u>	<u>81</u>	NR	<u>44</u>	<u>62</u>
ULN	15						

* ug/g, dry weight, June means for all years, except 1988 (single samples), and August means for 1985 to 1991 are based on duplicate samples and analysis. In 1984, triplicate samples were collected in August
NR - No Results, samples not collected
ULN - Phytotoxicology Section Upper Limit of Normal rural guideline, see appendix. Data underlined exceed ULN

Table 6: Concentrations of Aluminum and Sodium in Red Maple Foliage on Cornwall Island - June and August 1991

Location	June Concentrations*		August Concentrations*	
	Aluminum	Sodium	Aluminum	Sodium
S Shore Woodlot - W of Bridge - E of Bridge	67 265	35 <u>131</u>	79 225	28 <u>57</u>
More Remote - N. Point	100	<u>140</u>	95	36
ULN	500	50	500	50
* ug/g, dry weight, mean of duplicate samples and analysis in August. Single samples were collected in June ULN - Phytotoxicology Section Upper Limit of Normal rural guideline, see appendix. Data underlined exceed ULN				

Table 7: Concentrations* of Selected Elements in Manitoba Maple Foliage at Sites 1 and 7 - August 1991

Element	Site 1 (Bridge Area)	Site 7 (Remote)	ULN
Cadmium	DL	DL	1
Calcium	30000	26500	30000
Chloride	1300	500	1500
Chromium	0.6	DL	8
Cobalt	DL	DL	2
Copper	6	5	20
Iron	165	125	500
Lead	1	0.6	30
Magnesium	5550	3950	7000
Manganese	46	21	100
Molybdenum	0.4	DL	1.5
Nickel	5	2	5
Nitrogen	24450	21000	NG
Phosphorus	2280	1865	NG
Potassium	14000	8200	NG
Strontium	175	73	NG
Sulphur	2100	2500	4000
Vanadium	2	DL	5
Zinc	13	14	250

* ug/g, dry weight, mean of duplicate samples and analysis

DL - Concentration at or below analytical detection limit

ULN - Phytotoxicology Section Upper Limit of Normal rural guidelines (in the case of Mn, urban ULN), see appendix

NG - ULN not established

Table 8: Monthly Concentrations of Fluoride In Forage on Cornwall Island - 1989 and 1991

Site, Distance (km) & Direction from RMC	Fluoride Concentration* In Unwashed Forage										
	1989							1991			
	May	June	July	Aug.	Sept.	Oct.	Mean	June	July	Aug.	Mean
Bridge Site (1.5 NE) (uncut)	11	<u>17</u>	<u>48</u>	<u>39</u>	<u>24</u>	<u>33</u>	29	<u>56</u>	<u>64</u>	<u>22</u>	47
N. Point (2.0 NE) (hayfield/grazed)	7	3	<u>26</u>	8	3	<u>13</u>	10	<u>31</u>	<u>29</u>	<u>21</u>	27
P. Hopps (3.1 NE) (grazed)	5	2	<u>24</u>	8	4	11	9	<u>23</u>	<u>35</u>	9	22
Dump Site (3.3 NE) (hayfield)	8	2	<u>18</u>	9	5	<u>15</u>	10	8	<u>20</u>	10	13
E. Benedict (4.1 NE) (grazed)	4	3	<u>22</u>	8	4	6	8	<u>17</u>	<u>41</u>	9	22
N. Hopps (5.7 NE) (hayfield)	DL	1	<u>15</u>	5	3	3	5	5	12	6	8
P. Caldwell (1.8 NNE) (hayfield)	4	1	<u>17</u>	4	2	5	6	2	7	6	5
J. Thompson (1.7 N) (grazed)	5	4	9	6	5	7	6	4	8	4	5
Mean	6	4	22	11	6	12	10	18	27	11	19

* ug/g, dry weight, mean of duplicate samples and analysis

DL - at or below analytical detection limit

Note: Data underlined exceed Phytotoxicology Section Upper limit of Normal rural fluoride guideline of 12 ug/g, see appendix.

Table 9: Seasonal Mean (May-October) Fluoride Concentration at Forage Sites on Cornwall Island: 1978-1989

Site, Distance (km) & Direction from RMC	Seasonal Mean (six-month) Fluoride Concentration* In Unwashed Forage										
	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1989
Bridge Site (1.5 NE) (uncut)	58	51	52	68	41	52	92	36	26	37	29
N. Point (2.0 NE) (hayfield/grazed)	31	20	28	34	25	30	36	15	11	16	10
P. Hopps (3.1 NE) (grazed)	17	11	17	35	13	19	25	13	8	13	9
Dump Site (3.3 NE) (hayfield)	12	9	16	26	14	15	24	10	7	12	10
E. Benedict (4.1 NE) (grazed)	12	12	14	25	12	18	16	10	6	10	8
N. Hopps (5.7 NE) (hayfield)	9	9	7	18	9	13	14	5	6	6	5
P. Caldwell (1.8 NNE) (hayfield)	NR	NR	NR	NR	13	12	15	7	4	11	6
J. Thompson (1.7 N) (grazed)	12	10	12	22	10	11	13	8	5	11	6
Mean Common Sites	22	17	21	33	18	23	31	14	10	15	11
* ug/g, dry weight, mean seasonal values based on duplicate (1987 to 1989) or triplicate (1978 to 1979; 1983 to 1986) samples and analysis. A single samples per site was collected during 1980 to 1982 NR - No Results, samples not collected Note: 1982 to 1989 results based on ion selective electrode method; Alkali fusion method was used prior to 1982											

Table 10: Seasonal Mean (June to August) Fluoride Concentration at Forage Sites on Cornwall Island - 1977 to 1991													
Site, Distance (km) & Direction from RMC	Seasonal (three-month) Mean Fluoride Concentration* In Unwashed Forage												
	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1989	1991
Bridge Site (1.5 NE) (uncut)	88	72	43	43	71	36	48	123	38	26	41	35	47
N. Point (2.0 NE) (hayfield/grazed)	95	37	16	23	29	18	18	53	14	9	17	12	27
P. Hopps (3.1 NE) (grazed)	30	20	9	18	37	10	18	36	12	7	17	11	22
Dump Site (3.3 NE) (hayfield)	NR	13	6	12	26	9	10	31	7	5	11	10	13
E. Benedict (4.1 NE) (grazed)	23	14	11	13	25	10	17	23	9	6	13	11	22
N. Hopps (5.7 NE) (hayfield)	11	9	9	7	21	6	9	19	4	4	6	7	8
P. Caldwell (1.8 NNE) (hayfield)	NR	NR	NR	NR	NR	8	7	18	7	3	9	7	5
J. Thompson (1.7 N) (grazed)	19	8	10	11	15	7	9	15	8	5	11	6	5
Mean Common Sites	44	25	15	18	32	14	18	43	13	4	17	13	21
* ug/g, dry weight, mean of duplicate (1987 to 1991) or triplicate (1977-1979; 1983-1986) samples and analysis. A single sample was collected during 1980 to 1982 NR - No Results, samples not collected Note: 1982 to 1991 results based on ion selective electrode method; Alkali fusion method was used prior to 1982													

Table 11: Fluoride-Type Follar Injury Observed in Vicinity of South Shore-Bridge Area, Cornwall Island - 1991					
Species	Description of Follar Injury	Area(s) Injury Observed	Overall Site Injury(3)		
			Jun	Jul	Aug
Black Cherry	Reddish-brown necrosis tips/margins several leaves	Near River (1) Woodlot Area (2)	L T-L		L
Pin Cherry	Tan to reddish necrosis tips/margins some leaves	Woodlot Area (1) River Area (1) River Area (2) N. Point (2)	H H T	H	T-H T T
Wild Grape	Reddish-brown necrosis tips/margins some leaves	Woodlot area (1) River Area (1) Woodlot Area (2) River area (2) N. Point (2) A. Boots Area (2) Customs Area (1)	T H H H	T T-L T	T-L L T-L T-L T-L T
Manitoba Maple	Tan to reddish-tan necrosis tips/margins several leaves	Site 1 (2)	T	L	L-M
	Reddish-tan necrosis tips/margins some leaves	Site 33 (2) L. Point (2)		T T-L	T
Red/Silver Maple	Brown or blackish necrosis tips/margins some leaves	Woodlot (1) Woodlot (2) N. Point (2) A. Boots (2)	H T T	T T	T L T T
Plum	Red-brown necrosis tips/margins some leaves	Plum Plot (1) L. Point (2)	H	T T-L	H
Serviceberry	Red-brown marginal necrosis & cupping several leaves	River Area (1)	L-M		T-L
Staghorn Sumach	Red-brown to black necrosis tips/margins some leaves	Plum Plot Area (1) Woodlot Area (1) River Area (1) Woodlot Area (2)	T-L L	T-L	L T-L
	Marginal-interveinal & cupping several mature leaves	River Area (2)			L-M
Gladiolus	Reddish necrosis tips/margins some leaves	N. Point (2)		H	T
Cultivated Grape	Reddish necrosis tips/margins some leaves	A. Boots (2)		T	T
1 - Immediate impact area neighbouring to west of International Bridge 2 - Impact area neighbouring to east of Bridge 3 - Fluoride-type necrosis: T-Trace 0-1%; L-Light 2-10%; M-Moderate 11-35%					

Table 12: Results of Histological Examinations In 1989 and 1991				
Location	Follage Type	General Description of Injury	Examination Results	
			Typical of Fluoride	Not Typical
Follage Samples Collected In August 1989:				
S Shore W of Bridge	Black Cherry	Reddish-brown necrosis at margins	X	
S Shore E of Bridge	Manitoba Maple	Reddish-brown marginal necrosis		X
S Shore E of Bridge	Red Maple	Reddish-brown tip necrosis	X	
A. Boots Property	Black Cherry	Reddish marginal necrosis	X	
N. Point Property	Red Pine	Red tip necrosis on current year needles	X	
Follage Samples Collected In August 1991:				
S Shore W of Bridge	Black Cherry	Reddish-brown marginal necrosis/tipping		X
S Shore W of Bridge	E. White Pine	Red tip necrosis on current year needles		X
S Shore E of Bridge	E. White Pine	Red tip necrosis on current year needles		X
Martin Property	E. White Pine	Red tip necrosis on current year needles		X
A. Lazore Property	E. White Pine	Red tip necrosis on current year needles		X
N. Point Property	Red Pine	Red tip necrosis on current year needles		X

Table 13: Exceedances of Selected Air Quality Limits for Ambient Fluoride For Recent Growing Seasons that a Phytotoxicology Survey was Conducted on Cornwall Island: 1987, 1989 and 1991

Agency	Time/ Type	Allowable Conc. (ug/m ³)	% of Time Allowable Limit was Exceeded					
			1987		1989		1991	
			Sta. B	Sta. D	Sta. B	Sta. D	Sta. B	Sta. D
Ontario (Criteria)	24h/G	0.86	12.0	22.0	0.0	21.7	2.4	26.7
	24h/T	1.72	4.4	14.6	0.0	20.7	0.0	18.0
	30d/G	0.34	51.0	100.0	0.0	62.0	4.3	100.0
	30d/T	0.68	26.5	98.0	0.0	58.4	0.0	88.4
New York State (Standards)	24h/G	2.99	0.6	1.8	0.0	2.2	0.0	4.7
	1w/G	1.73	0.0	0.0	0.0	0.0	0.0	9.9
	1m/G	0.84	0.0	0.0	0.0	12.4	0.0	56.5
Canada (Objectives)	24h/G	0.85	12.0	22.2	0.0	21.7	2.4	26.7
	7d/G	0.55	16.6	43.7	0.0	31.5	0.0	56.5
	30d/G	0.35	47.7	100.0	0.0	60.6	4.3	100.0
	70d/G	0.22	100.0	100.0	59.7	100.0	88.8	100.0

Data from Environment Canada report - Ref. 2

Data reported as equivalent HF concentration corrected to a temperature of 25°C and a pressure of 760 mm Hg

G - gaseous fluoride; T - Total (gaseous + particulate); h - hours; d - days; w - week; m - month

Station B - E. Benedict Property, center of Island

Station D - Martin Property, south shore-bridge area

Note: 1989 data is not comparable to other year's data because of lack of confidence due to missing data in 1989

Table 14: Percentage of Time Winds were Recorded Blowing from the South, Southwest and West at the Ontario Hydro Climatic Station, Cornwall - May to August 1981-1991

Year	MAY			JUNE			JULY			AUGUST			MAY-AUGUST*		
	S	SW	W	S	SW	W	S	SW	W	S	SW	W	S	SW	W
1981	6	15	24	7	23	34	4	17	31	10	15	28	6	18	30
1982	9	11	19	5	23	20	2	24	34	3	23	33	5	20	26
1983	7	18	24	4	26	43	2	28	25	6	23	29	5	24	30
1984	3	17	39	4	22	38	2	26	48	2	23	34	3	21	40
1985	5	18	21	5	19	29	3	32	38	3	24	23	4	24	28
1986	6	13	20	2	18	31	2	13	32	7	24	29	4	17	28
1987	7	16	29	4	21	33	5	23	30	6	20	18	6	20	28
1989	8	17	25	8	14	29	1	20	43	6	25	25	6	19	32
1991	Data unavailable when report written														
* From May through to and including date of regular maple foliage collection: 1981-Aug 26; 1982-Aug 25; 1983-Aug 23; 1984-Aug 23; 1985-Aug 28; 1986-Aug 27; 1987-Aug 18; 1989-Aug 22; 1991-Aug 22															

Table 15: Total Amount (In mm) and Frequency (No. of Days) of Rainfall at Ontario Hydro Climate Station, Cornwall - May to August 1981-1991

Year	MAY		JUNE		JULY		AUGUST		MAY-AUGUST*	
	Total	Freq.	Total	Freq.	Total	Freq.	Total	Freq.	Total	Freq.
1981	109	15	95	14	69	8	122	16	382	50 (5)
1982	58	8	86	14	66	10	125	12	324	42 (8)
1983	88	17	79	11	92	11	61	8	317	46 (4)
1984	113	18	55	8	51	11	95	14	296	47 (7)
1985	68	12	148	18	68	11	70	9	336	48 (6)
1986	90	18	108	13	165	14	104	16	466	60 (7)
1987	64	18	82	18	111	15	98	15	314	57 (6)
1989	92	23	99	13	73	6	108	15	370	54 (6)
1991	79	11	27	3	49	12	125	12	267	37 (8)
Norms**	70	12	70	11	76	11	99	11		

* May through to and including day of regular foliage collection: 1981-Aug 26; 1982-Aug 25; 1983-Aug 23; 1984-Aug 23; 1985-Aug 28; 1986-Aug 27; 1987-Aug 18; 1989-Aug 22; 1991-Aug 22

** Rainfall normals taken from Canadian Climate Normals, Atmospheric Environment Service, Environment Canada, Toronto

() Number of days with rain during two week period prior to date of foliage collection

Note: Data is shown only for years a Phytotoxicology Survey was completed on Cornwall Island

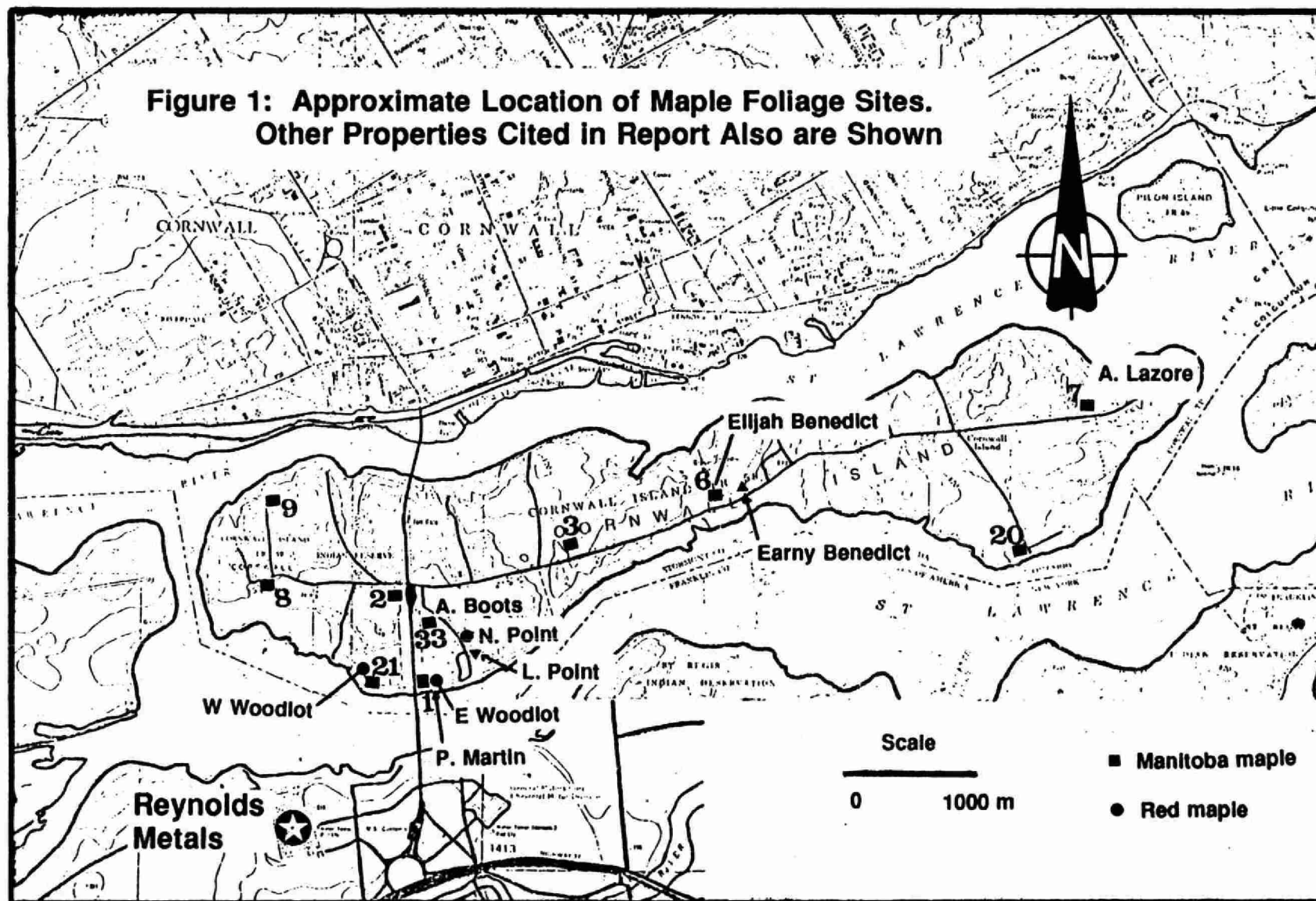
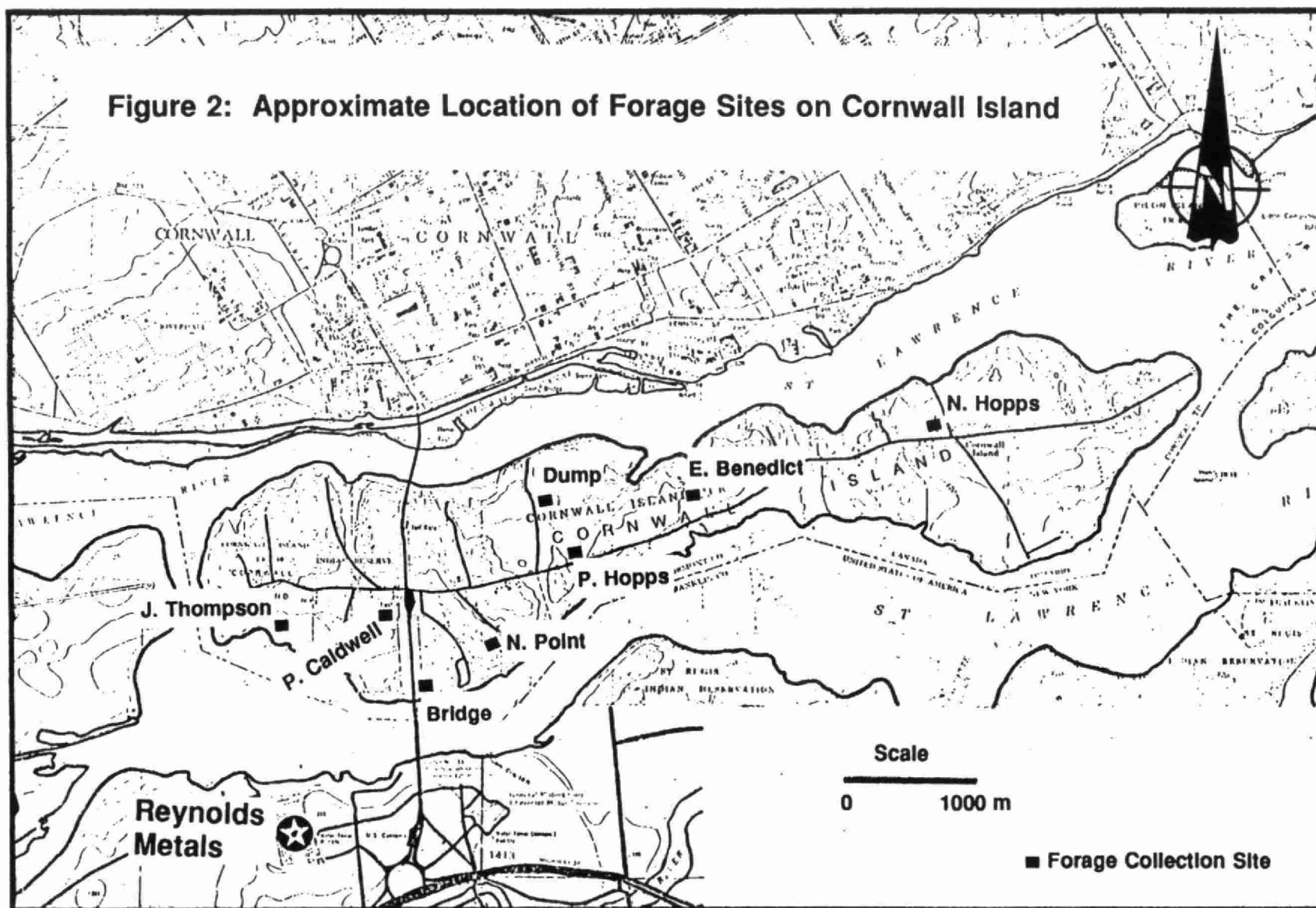


Figure 2: Approximate Location of Forage Sites on Cornwall Island



Appendix

Derivation and Significance of the MOE Phytotoxicology "Upper Limits of Normal" Contaminant Guidelines.

The MOE Upper Limits of Normal (ULN) contaminant guidelines represent the expected maximum concentration in surface soil, foliage (trees and shrubs), grass, moss bags, and snow from areas in Ontario not exposed to the influence of a pollution source. Urban ULN guidelines are based on samples collected from urban centres, whereas rural ULN guidelines were developed from non-urbanized areas. Samples were collected by Phytotoxicology staff using standard sampling procedures (reference: Ontario Ministry of the Environment 1992, *Phytotoxicology Field Investigation Manual*). Chemical analyses were conducted by the MOE Laboratory Services Branch.

The ULN is the arithmetic mean plus three standard deviations of the suitable background data for each chemical element and parameter. This represents 99% of the sample population. This means that for every 100 samples that have not been exposed to a pollution source, 99 will fall within the ULN.

The ULNs do not represent maximum desirable or allowable limits. Rather, they are an indication that concentrations that exceed the ULN may be the result of contamination from a pollution source. Concentrations that exceed the ULNs are not necessarily toxic to plants, animals, or people. Concentrations that are below the ULNs are not known to be toxic.

ULNs are not available for all elements. This is because some elements have a very large range in the natural environment and the ULN, calculated as the mean plus three standard deviations, would be unrealistically high. Also, for some elements, insufficient background data is available to confidently calculate ULNs. The MOE Phytotoxicology ULNs are constantly being reviewed as the background environmental data base is expanded. This will result in more ULNs being established and may amend existing ULNs.



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